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MURPHY CREEK HYDROELECTRIC PROJECT:

ASSESSMENT OF NOISE AND VIBRATION

FROM CONSTRUCTION

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SUMMARY

The effects of construction noise and vibration on communities adjacent to the proposed site of the Murphy Creek Hydroelectric Project have been predicted by Harford, Kennedy, Wakefield Ltd. at the request of B. C. Hydro and Power Authority. Project plans and construction schedule were reviewed with B. C. Hydro and where necessary, preliminary assumptions were made in order to permit quantitative estimations of noise levels.

Noise level readings of construction equipment and activities were made at Revelstoke hydroelectric construction site and elsewhere to obtain suitable input data for the noise analysis. Field studies including measurement of existing noise levels and measurement of sound attenuation (sound decay) from the proposed site to adjacent communities were also carried out at the Murphy Creek Site. This field data, together with data available in the literature, permitted quantitative predictions of noise levels to be made at various receptor locations in the communities of Oasis and Rivervale and subsequently to anticipate degrees of noise impact.

The descriptor used for the noise predictions was the Yearly Day/Night Average Sound Level, abbreviated L_{dny}. This descriptor has been used almost universally in recent years for environmental noise studies since it correlates closely with the degree of activity interference and annoyance experienced by noise receptors. To most accurately reflect local conditions (eg. existing noise levels, community attitudes, tonal or impulsive qualities of intruding noise) the L_{dny} values were "normalized" by adding or subtracting corrections of 5 or 10 dB as suggested by the United States Environmental Protection Agency and other authorities. Noise impacts were predicted directly from these normalized L_{dny} values. Impact was categorized as "Insignificant", "Low", "Moderate", "High", or

"Extreme". To the layman, the respective degrees of impact might be expressed more meaningfully as "Not Annoying", "Slightly Annoying", "Moderately Annoying", "Very Annoying" or "Extremely Annoying".

The only vibration that would be experienced in Oasis and Rivervale would be that associated with blasting. However, it was concluded that neither vibration nor noise from blasting would have any serious impact on these communities providing that sequential delay blasting techniques are used to limit the explosive charge per delay to about 125 kg and providing that the number of blasts per day is small (i.e. 1 to 3) and blasts are scheduled to result in the least possible interference with community activities (particularly sleep).

Construction noise, apart from blasting, would vary as the project progresses through various phases of construction. For the purpose of predicting noise impact, the major phases indentified were Mobilization, Rock Excavation, Earth Excavation/Concrete, and Site Cleanup. If no mitigative measures are implemented, the noise impacts predicted at representative community locations shown in Figure S1 would be as indicated in Table S1.

Limited possibilities are available to mitigate the predicted noise impacts. Noise produced by the predominant sources (rock drills and air compressors) could be limited by specifying that the contractor utilize some of the relatively quiet equipment which has become available over the past few years and in at least one case, truck noise could be reduced by a roadside barrier. It is assumed for the purpose of analysis that noise produced at night (i.e. between 22:00 hours and 07:00 hours) would be 10 dBA more significant in creating an adverse impact than noise produced

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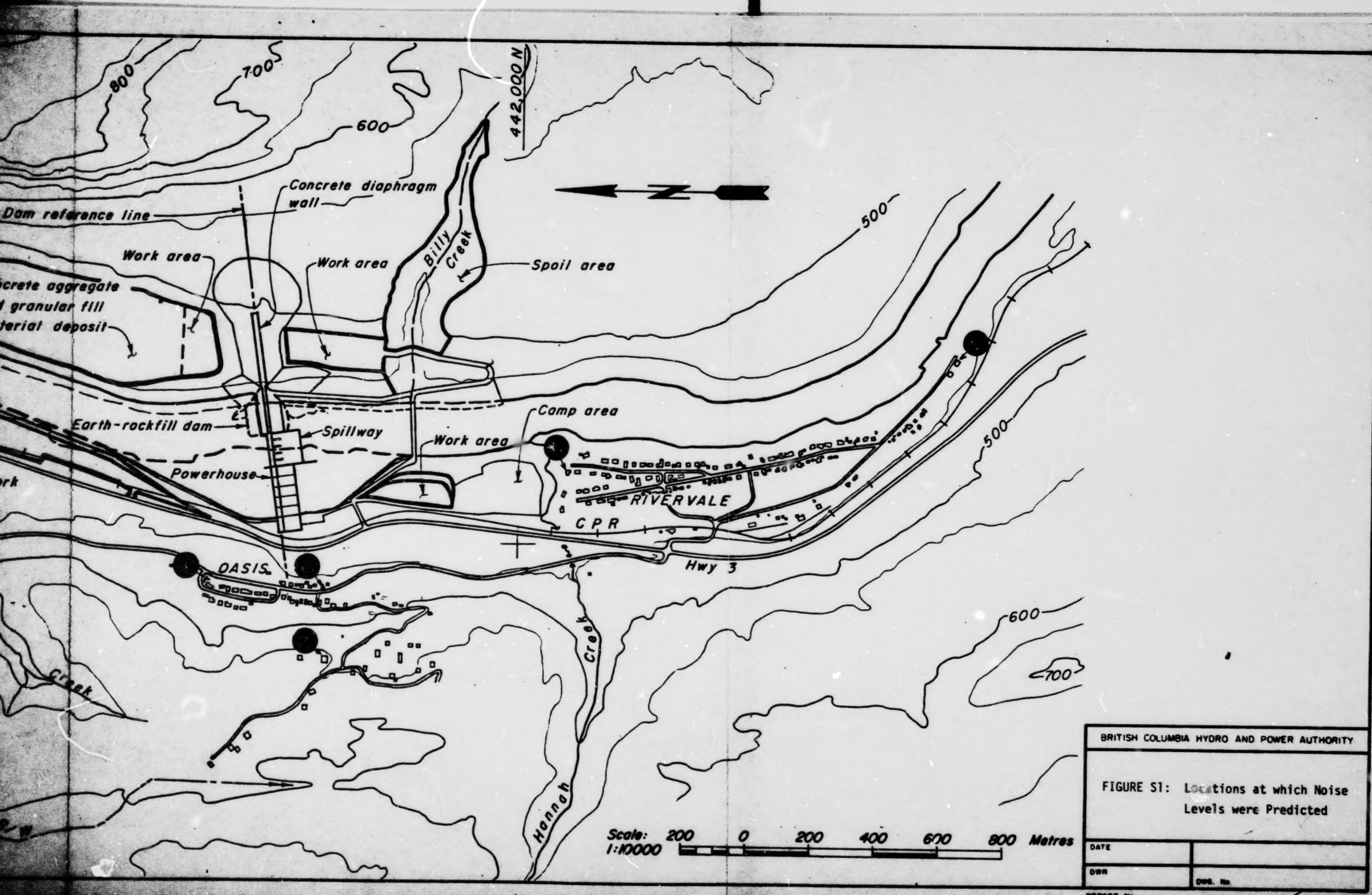

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FIGURE S1: Locations at which Noise Levels were Predicted

DATE	
DWN	DWG. No

REPORT No

Construction Phase	Normalized L_{dny} (dBA) at Receptor Locations (Refer to Figure S1)									
	0		02		03		R		R2	
Mobilization	72	High	77	Extreme	68	Moderate	71	High	56	Low
Rock Excavation	75	High	80	Extreme	71	High	74	High	59	Low
Earth Excavation and Concrete	67	Moderate	67	Moderate	62	Low	70	High	60	Low
Site Cleanup	55	Insignificant	53	Insignificant	54	Insignificant	58	Low	44	Insignificant

Note 1) Values in table are for project noise without additive effect of existing noise because noise impact is predicted from normalized L_{dny} of intruding noise (i.e. project noise). (Where existing noise is 10 dBA or more below project noise, the additive effect is negligible.)

Note 2) Noise impact is "Insignificant" for normalized $L_{dny} \leq 55$ dBA

Noise impact is "Low" for normalized 55 dBA $< L_{dny} \leq 62$ dBA

Noise impact is "Moderate" for normalized 62 dBA $< L_{dny} \leq 69$ dBA

Noise impact is "High" for normalized 69 dBA $< L_{dny} \leq 76$ dBA

Noise impact is "Extreme" for normalized 76 dBA $< L_{dny}$

TABLE S1: Normalized L_{dny} of Project Noise and Resultant Noise Impact at Receptor Locations (No Mitigative Measures)

during the day. Noise impact could also be reduced substantially by curtailing some of the noisiest activities during the nighttime hours and making up for this lost production by utilizing extra equipment during the daytime or by continuing a particular activity over a longer time period.

Other available means of mitigating noise impact would involve noise control at the residences which are affected by the noise. Such measures as fresh air ventilation or air conditioning to alleviate the need for open windows and installation of storm windows and solid fences on the noise exposed sides of residences could be used in lieu of noise control on the site or in addition to noise control on the site.

The affects of these various possibilities for noise mitigation are illustrated in Table S2 which, for the sake of clarity, shows only the noisiest (Rock Excavation) phase. It is apparent from this table that any of the various mitigative measures identified could reduce noise impact significantly.

	Normalized L_{dny} (dBA) of Project Noise and Resultant Degree of Impact Various Receptor Locations (Rock Excavation Phase)				
	0	02	03	R	R2
No mitigative measures	75 High	80 Extreme	71 High	74 High	59 Low
Specified noise limits on rock drills and compressors (90 dBA for drills and 70 dBA for compressors at 15 m)	70 High	72 High	66 Moderate	72 High	58 Low
Specified noise limits on rock drills and compressors as above plus provision of 3 m high roadside barrier to shield Riverside from noise produced by trucks hauling waste during rock excavation phase from right bank to waste dump in vicinity of Billy Creek.	70 High	72 High	66 Moderate	69 Moderate	54 Insignificant
Noise control at residences (varying degrees)	65-70 Moderate-High	70-75 High	60-65 Low-Moderate	61-66 Low-Moderate	50-55 Insignificant
Elimination of nighttime (22:00 hours to 07:00 hours) drilling on right bank and nighttime use of left bank waste dump during mobilization and rock excavation phases plus elimination of nighttime earth excavation on left bank during earth excavation and concrete phase. In addition, increase by 60% the number of drills, trucks, loaders, dozers, etc. to compensate for curtailed nighttime activities.	68 Moderate	73 High	64 Moderate	69 Moderate	54 Insignificant

TABLE S2: Effect of Various Mitigating Measures on Predicted Impact at Receptor Locations during Rock Excavation Phase.

1.0 INTRODUCTION

At the request of British Columbia Hydro and Power Authority, Harford, Kennedy, Wakefield Ltd. has evaluated the possible effects of noise and vibration on the communities of Oasis and Rivervale during construction of the proposed Murphy Creek Project. The scope of this work included the following:

- measurement of existing community noise levels and prediction of noise and vibration levels likely to occur during construction
- assessment of the significance of any noise or vibration impacts identified
- identification of possible solutions or mitigative measures
- conclusions of study

This report documents the noise and vibration evaluations carried out by Harford, Kennedy, Wakefield Ltd.

2.0 NOISE AND VIBRATION ASSESSMENT

2.1 NOISE AND VIBRATION ASSESSMENT APPROACH

The methodology used to assess construction noise impact in Oasis and Rivervale consisted of several steps as listed below:

i) The latest construction plans and schedule (February 5, 1982) were reviewed with the designers in order to determine, as accurately as possible, the number and types of machines to be used at various times and at various locations throughout the construction project. Since much of this information is unresolved at present, it was necessary in most cases to make assumptions and estimates based on previous experience with similar projects. Noise level data (sound pressure level at 15 m from the source) was obtained from the literature and from measurements conducted by Harford, Kennedy, Wakefield Ltd.

ii) The amount of sound attenuation (i.e. sound level reduction) that would occur between various areas of the construction site and a number of representative receptor locations was determined both by direct measurement and theoretical prediction.

2.1 NOISE AND VIBRATION ASSESSMENT APPROACH (Cont'd)

iii) Noise levels at the receptor locations resulting from each individual noise source were predicted by subtracting the expected attenuations calculated in (ii) above, from the source levels. Duty factors of the equipment (i.e. estimated percentage of time at full power) and numbers of equipment were taken into account in these calculations. The total noise level was then calculated for each receptor location by combining the sound energies arriving from all individual sources.

iv) Existing noise levels were measured in Oasis and Rivervale since this information is required to fully assess the impact of construction noise.

v) Having predicted the future noise levels and having measured the existing levels, the impact of future noise levels was evaluated. This was done by comparing predicted noise levels with recognized criteria and with the existing levels.

vi) The only vibration expected to result in Oasis and Rivervale would be that associated with blasting. The level of ground vibration was predicted using empirical prediction models reported in the literature. The effects of ground vibration were predicted by relating predicted levels of vibration to recognized criteria.

In the above procedure, existing noise levels, predicted noise levels and noise level criteria are all expressed in terms of the Yearly Day Night Average Sound Level, L_{dny}. The L_{dny} is a long term (i.e. yearly) average of the Day Night Average Sound Level, L_{dn}, which in turn is derived from the Equivalent Sound Level, Leq, by adding a 10 decibel weighting factor to noise which occurs during the most sensitive nighttime hours (10:00 p.m. to 7:00 a.m.). The Equivalent Sound Level, Leq, which is the basis of the L_{dny}, is the level of a steady A-weighted[1] sound which would result in the same total sound energy over a specified time as does the actual time-varying sound level over that time.

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[1] A-weighted decibel (dBA): The unit of sound pressure level most commonly used when dealing with the effect of noise on people. This level is obtained by summing the contributions from all audible frequencies after applying a weighting network that approximates the frequency response (sensitivity) of the human ear.

2.1 NOISE AND VIBRATION ASSESSMENT APPROACH (Cont'd)

The 10 dB nighttime weighting factor which is included in computing the L_{dn}, was originally implemented by the United States Environmental Protection Agency (1) based on a number of previous studies which indicated that such a weighting would adequately compensate for the fact that noise during the night is much more disruptive and annoying than noise during the day.

The L_{eq} and L_{dn} both employ the average energy concept and hence varying noise levels are averaged logarithmically. This results in peak noise levels receiving more emphasis than they would if the levels were averaged arithmetically. For this reason, the L_{eq} and L_{dn} are sensitive to high level intrusive noises even though these noises may be of short duration.

In 1974, the United States Environmental Protection Agency (EPA) identified in their "Levels Document" (1), values of L_{eq} and L_{dn} above which adverse effects on public health and welfare begin to occur. The values of L_{eq} and L_{dn} so identified assume a relatively long averaging time, in the order of a year. While it is recognized that there will be seasonal and day to day variations in the L_{eq} and L_{dn}, yearly averages correlate well with public health and welfare effects. Hence the yearly average of L_{dn}, referred to as the L_{dny}, has been used for this study.

2.2 DESCRIPTION OF ASSUMED CONSTRUCTION EQUIPMENT (ACTIVITIES)

For the purpose of quantifying noise levels, the project can be divided into the following major phases:

Mobilization:	6-12 months	(Year 0)
Rock Excavation:	2 years	(Years 1 and 2)
Earth Excavation and Concrete Work:	2 years	(Years 3 and 4)
Site Cleanup:	6 months	(Year 5)

These phases would tend to blend together with some overlap and therefore there would be a gradual increase or decrease in noise levels from one phase to the next.

The particular project scheme that has been evaluated is referred to as the 5 unit Kaplan 424 scheme as portrayed by British Columbia Hydro (see Figure 1). The following preliminary information on construction procedures and equipment was assumed by Harford, Kennedy, Wakefield Ltd. based on discussions with B. C. Hydro personnel.

Mobilization

i) The level of activity on site (and hence noise levels) during the mobilization period would gradually increase from no activity to that predicted for the rock excavation phase.

Rock Excavation Phase

ii) Ten 65-115 mm bore rock drills (eg. Air Tracs) with individual compressors would likely operate 5 to 6 days per week on the right (west) bank during two shifts and possibly three shifts per day.

iii) One blast per day would be required. Volume of rock blasted per day would be in the order of 3500 m^3 and explosive charge required would be approximately 0.6 kg per m^3 of rock. (If more frequent, smaller blasts are necessary, the resultant annoyance to nearby residents would be greater but an increase from one to two or three blasts per day would only increase annoyance slightly).

350
400
450
444,000 N
446,750 E
Concrete aggregate
COLUMBIA
CPR
Hwy No 3
To Castlegar
(rock spoil, waste area)
450
500
446,000 E
444,000 N
McNally Cr.
600

Aggregate Processing Plant

Concrete aggregate and granular fill material deposit

Acoustic Centre for Loaders, Backhoe, Trucks

Possible Downstream Spoil Area

Acoustic Centre for Pile Driver, Drag Line

Trucks Crossing River

Acoustic Centre for Rock Drills, Loaders, Trucks

Concrete Batch Plant

Acoustic Centre for Buses, Concrete Transit Trucks

COLUMBIA RIVER

RIVERVALE

CAMP

OASIS

CPR

To Trail

Hwy No. 3

Scale 1:5000 50 0 50 100 150 200 Metres

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FIGURE 1: Proposed Project Layout

DATE

DWN

DWG No

2.2 DESCRIPTION OF ASSUMED CONSTRUCTION EQUIPMENT (ACTIVITIES) (Cont'd)

Rock Excavation Phase (Cont'd)

iv) Two 5-10 m^3 loaders and eight 45-75 tonne off-highway trucks would operate on the right bank during all three shifts removing rock from the site to an upstream waste dump on the left bank in the vicinity of Billy Creek. (For the purpose of this noise study it is assumed that each of these two dumps is utilized equally). Except when trucks are hauling waste across the river to the dump near Billy Creek, loaders and trucks would generally be operating at the base of a rock face which would be blasted progressively from the existing right bank of the river towards the community of Oasis. Hence the face would provide acoustic shielding between the trucks and loaders and the residences in Oasis (and to a lesser extent Rivervale).

v) Two bulldozers would likely operate continuously spreading rock in waste dumps located on the right and left banks.

vi) The proposed cellular cofferdam would likely be constructed from sheet piles installed by a pile driver which would operate for up to two shifts per day (day and afternoon shifts).

vii) Several buses would be required for transporting workmen at shift changes and lunch breaks.

Earth Excavation and Concrete Phase

viii) Two loaders and eight trucks of the size described above, plus one hydraulic backhoe excavator would likely operate five to six days per week on the left bank during all three shifts removing earth from the dam axis to a spoil area, probably downstream.

ix) Two bulldozers would likely operate continuously in the downstream spoil area referred to in (viii) above. For the purpose of this study the location of this spoil area has been assumed as indicated in Figure 1 although this is only one of several possible locations.

x) One 230 tonne crane would be used to operate a drag line and perform other operations on site for up to three shifts.

xi) An aggregate processing plant consisting of various screens, crushers and a front end loader would be located on the left bank, upstream of the dam axis as indicated in Figure 1. This facility would likely operate for up to two shifts per day (day and afternoon shifts).

xii) Processed aggregate would be transferred by conveyor or cable to a concrete batch plant located downstream of the dam axis on the right bank as indicated in Figure 1. The batch plant would normally operate during the day and afternoon shifts only although occasionally, concrete pour requirements could demand extended hours.

2.2 DESCRIPTION OF ASSUMED CONSTRUCTION EQUIPMENT (ACTIVITIES) (Cont'd)

Earth Excavation and Concrete Phase (Cont'd)

xiii) Approximately five transit trucks would transport concrete from the batch plant to various areas of the site, primarily during the afternoon shift.

xiv) Several electric (whirley) cranes and two 30 tonne mobile cranes would be in use throughout all three shifts.

xv) Up to eight buses would be required for transporting workmen at each shift change and lunch break.

Site Cleanup

xvi) It is not possible to anticipate exactly what activities and equipment would be occurring on site during this period. Therefore a typical noise level quoted in Reference (2) for site cleanup on powerplant construction projects has been assumed.

The construction equipment referred to above does not represent a complete list but does include those items which are expected to be the most significant sources of noise. Where specific numbers are mentioned, these are assumptions made for the purpose of this study based on the best available estimates from B.C. Hydro. Actual numbers may be lower or higher and the type of equipment may vary as the final decision on equipment used will be up to the contractor.

2.3 EXISTING NOISE LEVELS IN COMMUNITIES ADJACENT TO SITE

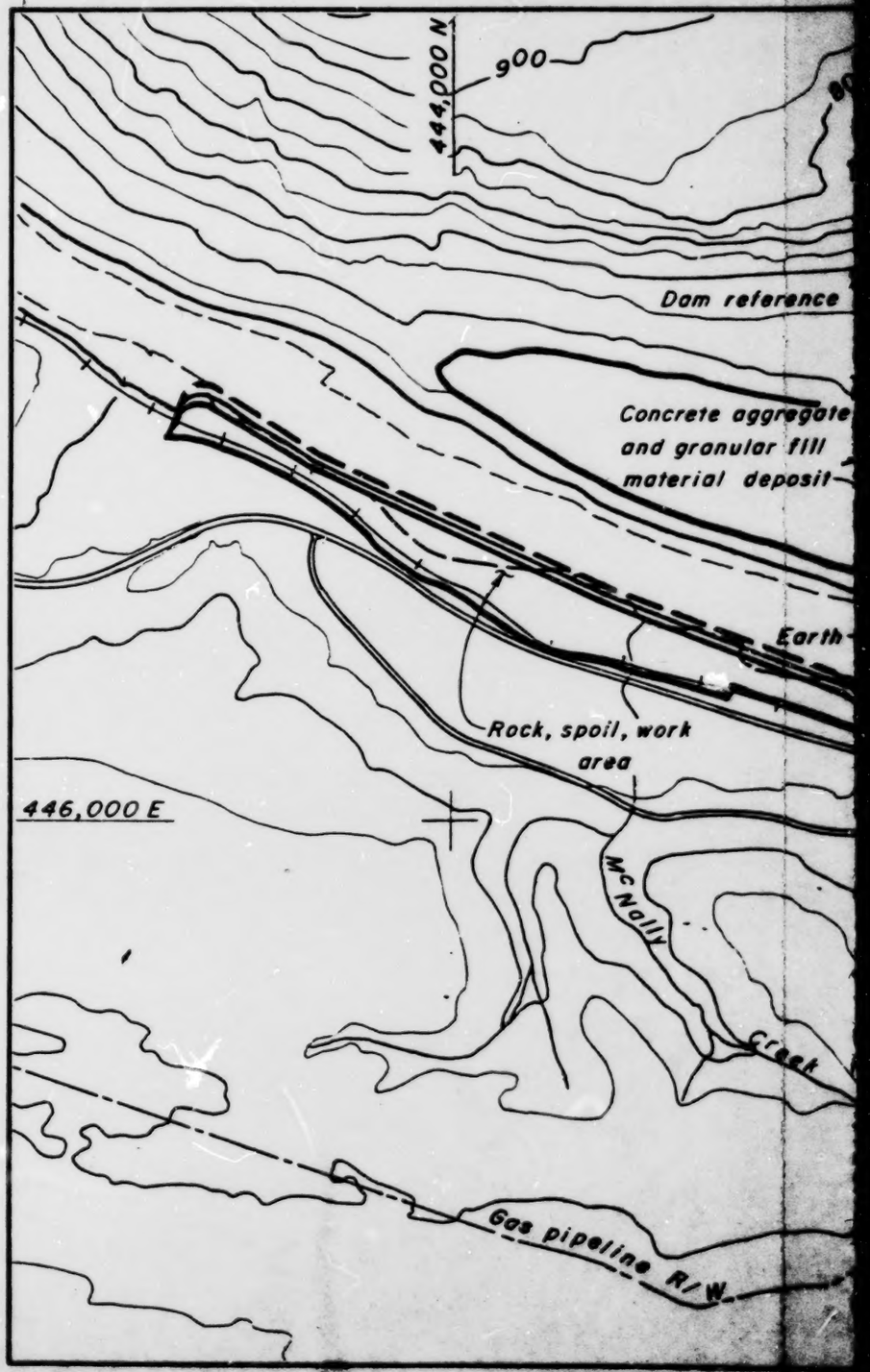
Baseline noise monitoring was conducted at 11 Hanna Drive in Oasis (location O in Figure 2) and at 536 3rd Avenue in Rivervale (location R in Figure 2). Noise levels measured at locations O and R are indicative of the levels which exist throughout most of Oasis and Rivervale respectively. At the Oasis location, the noise environment is largely influenced by highway and local traffic with some contribution from trains and aircraft. At the Rivervale location, the background noise level is established by a nearby creek. Occasionally, high level noise from trains interrupts the otherwise steady background noise level.

The measured baseline noise data is summarized in Table 1. Photographs of the monitoring locations and descriptions of the data acquisition systems are contained in Appendix A.

2.4 SOUND ATTENUATION BETWEEN SITE AND ADJACENT COMMUNITIES

For a point source located outdoors, sound decays due to spherical spreading by 20 log r_2/r_1 decibels as it propagates from distance r_1 to r_2. Additional attenuation occurs due to wind, atmospheric absorption, ground effect and shielding.

The primary effect of wind is to provide additional attenuation when the noise source is downwind of the receiver. Atmospheric absorption is temperature and humidity dependant and is directly proportional to distance. Ground effect attenuation, which is caused by interference between the direct sound wave and the ground reflection, occurs only over "soft" ground at grazing angles of incidence (i.e. when sound strikes the ground at an enclosed angle of 5° or less). Its effect is most predominant in the mid frequency range (i.e. 250-1000 Hz).



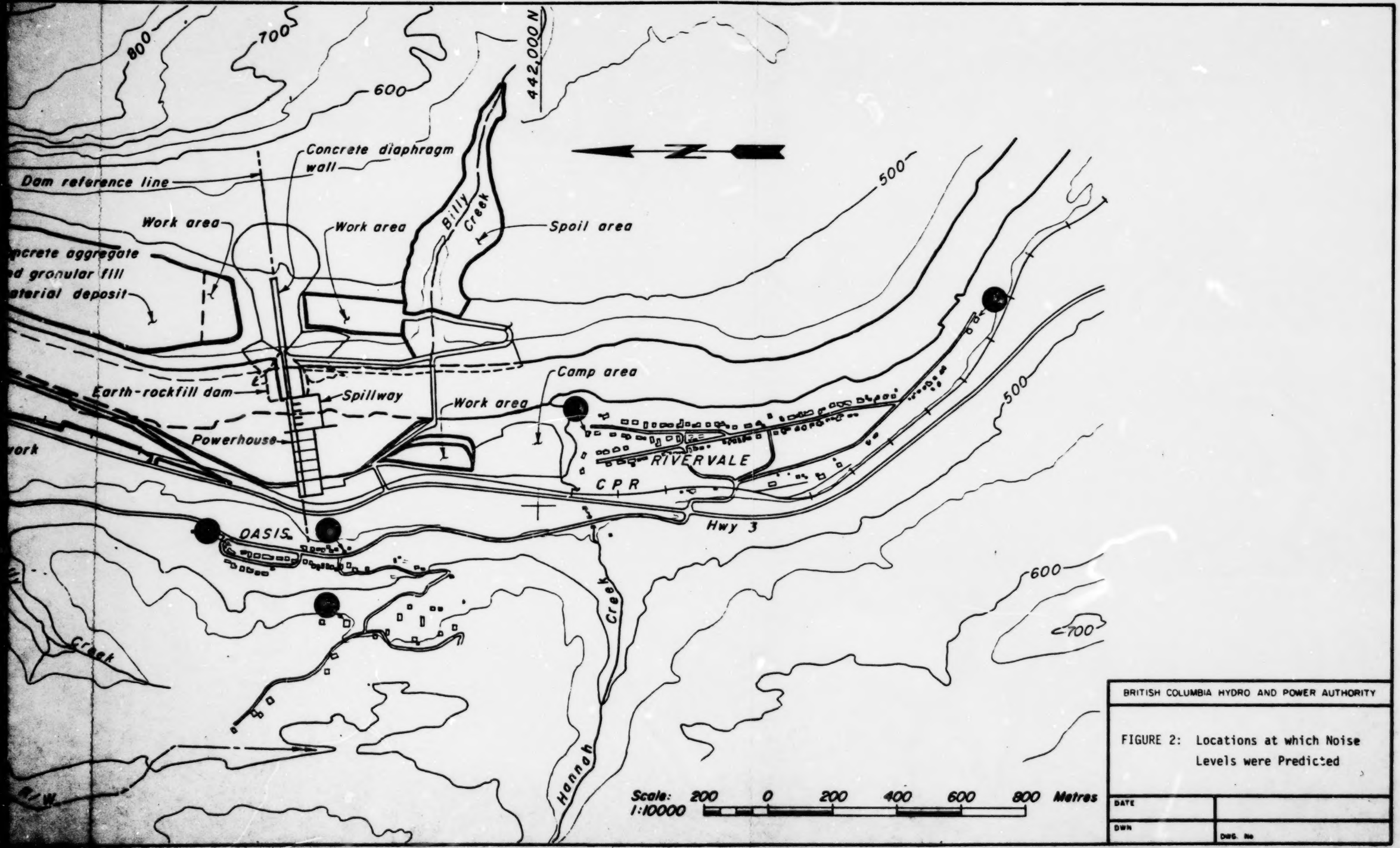


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FIGURE 2: Locations at which Noise Levels were Predicted

DATE	
DWN	DWG. No

REPORT No

Monitoring Location	Period of Noise Monitoring	Leq (24) (dB)	L_d (dB)	L_n (dB)	L_{dn} (dB)
11 Hanna Drive, Oasis	Wed. January 27, 1982 12:00 - 12:00 hours	-	-	-	54
	Thurs. January 28, 1982 14:00 - 07:00 hours	53*	54*	48	56*
563 3rd Avenue, Rivervale	Wed. January 27, 1982 14:00 - 14:00 hours	42	43	39	46

Leq (24) : 24 hour equivalent sound level (an energy average over 24 hours)
L_d : daytime equivalent sound level (Leq between 07:00 and 22:00 hours)
L_n : nighttime equivalent sound level (Leq between 22:00 and 07:00 hours)
L_{dn} : day-night equivalent sound level (24 hour energy average computed after adding a 10 dB weighting factor to the nighttime hours between 22:00 and 07:00)

* Estimate based on assumption that L_d equals the measured Leq from 14:00 to 22:00 hours.

TABLE 1: Measured Baseline Noise Levels

2.4 SOUND ATTENUATION BETWEEN SITE AND ADJACENT COMMUNITIES (Cont'd)

Attenuation due to shielding occurs when a barrier such as uneven terrain or buildings blocks the line of sight between noise source and receiver. This form of attenuation is directly proportional to frequency except that at high frequencies (i.e. above 1000 Hz) atmospheric turbulence can cause scattering of sound back into the "shadow" zone of the barrier and hence shielding sometimes decreases at high frequencies.

For the purpose of this study a number of specific source to receiver paths have been considered. Several source locations representing the acoustic centres of particular construction operations or groups of equipment have been denoted on Figure 1 by numbers 1 through 7. A total of five different receiver locations are indicated in Figure 2 as 0, 02 and 03 (in Oasis) and R and R2 (in Rivervale).

Since wind generally tends to blow along a river valley, it is unlikely that the proposed construction site would be downwind of Oasis on many occasions and hence attenuation due to wind would not be a significant factor as far as Oasis is concerned. In the case of Rivervale, it is estimated, based on meteorological records from Trail Tadanac, that the proposed construction site would be downwind of Rivervale roughly 25% of the time. However, the extra sound attenuation that would result in lower noise levels at Rivervale during that portion of the time has been ignored in this noise analysis since the extra attenuation to be expected under these conditions is highly variable and difficult to predict.

2.4 SOUND ATTENUATION BETWEEN SITE AND ADJACENT COMMUNITIES (Cont'd)

In order to predict representative values of atmospheric absorption, meteorological records of mean temperature and humidities at various times of the day and at various times throughout the year were reviewed. (The meteorological data used were for Cranbrook since that is the closest location at which detailed records of relative humidity are available.) Although the calculated values of attenuation were generally lowest throughout the summer months, the difference between summer and other seasons was not great. Therefore these "worst case" summer conditions have been assumed to occur all year round.

Attenuation due to ground effect and shielding is difficult to predict theoretically over irregular terrain. For this reason, field measurements of total attenuation over several propagation paths of interest were made. Air temperature and humidity were recorded during these measurements to permit adjustment of the measured data to the more standard conditions assumed for the study.

The sound attenuation measurements were made by firing a shot gun blast at various locations on site and measuring the resultant noise level at both the source location and at various receiver locations in Oasis and Rivervale. The amount by which the sound level was reduced in travelling from the sound source location to a particular reciever location is the "sound attenuation" (in decibels). Since the objective of these measurements was only to determine the difference in sound level between source and receiver over various propagation paths, the absolute sound level of the sound source was unimportant. The reason for using a shotgun, was simply to achieve a very loud signal and hence a high signal-to-noise ratio at the receiver location.

2.4 SOUND ATTENUATION BETWEEN SITE AND ADJACENT COMMUNITIES (Cont'd)

Since sound attenuation varies with the frequency range of the sound, the attenuation measurements were conducted independently for each frequency range (i.e. in each octave band[1]). Hence the attenuation data obtained from these measurements could later be utilized to carry out noise level predictions for any type of sound source (eg. for any type of construction equipment) regardless of its frequency spectrum or source level (i.e. loudness).

As a cross check, attenuation due to spherical spreading plus atmospheric absorption alone were predicted theoretically. The agreement between measured and calculated attenuation values was good at low frequencies. At higher frequencies, extra attenuation due to ground effect and/or shielding was evident in the measured data. The attenuation values used to predict community noise levels are tabulated in Table 2. These are derived primarily from the measured data but incorporate some adjustments to account for slight differences in air temperature, humidity and source-receiver distances.

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[1]Octave band: A range of audio frequencies bounded by an upper frequency which is twice the lower frequency and designated by its centre frequency (in Hz). The octave bands commonly used in noise analyses are those designated by the centre frequencies 63, 125, 250, 500, 1000, 2000 and 4000 Hz.

Source - Receiver Path (Refer to Figures 1 & 2)	Octave Band Centre Frequency (Hz)						
	63	125	250	500	1000	2000	4000
1 - 0	27	29	31	39	38	39	40
1 - 02	29	29	29	30	31	35	43
1 - 03	29	33	38	48	46	41	42
1 - R	49	54	55	55	43	47	66
1 - R2	52	58	64	66	63	64	100
2 - 0,	22	22	22	22	23	24	27
2 - 02	27	27	27	28	29	31	36
2 - 03	33	37	42	52	50	43	41
2 - R	48	53	54	54	41	44	60
2 - R2	51	57	63	65	61	61	94
3 - 0	32	32	33	39	40	39	44
3 - 02	33	33	34	35	36	40	50
3 - 03	31	35	41	50	49	45	43
3 - R	34	36	37	41	38	43	58
3 - R2	42	43	44	46	51	62	95
4 - 0	32	32	33	39	41	42	52
4 - 02	34	34	35	36	38	44	59
4 - 03	31	35	41	50	50	48	50
4 - R	34	36	37	41	38	43	58
4 - R2	41	42	43	45	50	61	94
5 - 0	31	31	32	38	39	40	48
5 - 02	33	33	34	35	36	42	55
5 - 03	32	36	42	51	50	47	47
5 - R	31	33	34	37	34	37	48
5 - R2	41	42	43	45	50	61	94
6 - 0	24	26	28	36	35	35	35
6 - 02	28	28	28	29	30	33	40
6 - 03	31	35	40	50	48	43	44
6 - R	46	51	52	52	39	41	56
6 - R2	51	57	63	65	61	61	94
7 - 0	34	34	35	41	43	44	54
7 - 02	35	35	36	37	39	45	60
7 - 03	32	36	42	51	51	49	51
7 - R	36	38	39	43	40	45	60
7 - R2	42	43	44	46	51	62	95

TABLE 2: Sound Attenuation (in dB) over Various Source - Receiver Paths

2.5 PREDICTED NOISE AND VIBRATION LEVELS

The specific receptor locations indicated in Figure 2 were selected for the following reasons:

- Locations 0 and 02 in Oasis, are "worst case" locations; 0, because of its close proximity to the site and lack of acoustic shielding and 02 because of a lack of both shielding and ground effect due to its position at the top of a cliff overlooking the site.
- Location 03 is located in that portion of Oasis which would be most protected from construction noise.
- Location R is the location in Rivervale that would be most exposed to construction noise.
- Location R2 is the location of the furthest residence likely to be affected by construction noise.

The L_{dny} values predicted for each of the above locations are listed in Table 3. Noise levels at other locations can be estimated approximately by considering their proximity to the various locations at which detailed analyses were carried out. Table 4 presents typical average L_{dny} values for various types of communities. This table is included here to give some perspective to the values presented in Table 3.

The noise level predictions in Table 3 are presented in terms of L_{dny} values which are averages, and while it is true that noise levels over short periods could exceed these values, they are likely to be fairly constant at a distance from the construction site. It is unlikely that instantaneous noise levels (aside from blasting) would exceed these average values by more than about 5 dBA because of the large number of continuously operating sources that would be on site. This is more easily appreciated if one considers that, in order to increase levels by only 3 dBA, the source power must be doubled (by operating twice as many noise sources for example).

Project Phase	Predicted L_{dny} Values (dBA) During Construction at Various Receiver Locations				
	Oasis			Rivervale	
	0	02	03	R	R2
Present (i.e. pre-construction)	55(1)	55(2)	55(2)	46	46(2)
Mobilization(3) (6 - 12 months)	72	77	67	63	49
Rock Excavation (2 years)	75	80	70	66	51
Earth Excavation and Concrete (2 years)	67	67	58	65	55
Site Cleanup(4) (6 months)	58	57	58	54	57

Note 1: Average of L_{dn} values measured on two consecutive days.

Note 2: Estimated values

Note 3: L_{dn} values are expected to increase gradually during the Mobilization Phase from present values to the values predicted during the Rock Excavation Phase. Assuming that the average level of activity during the entire Mobilization Phase would be 50% less than during the Rock Excavation Phase, L_{dny} values (i.e. long term average noise levels) during Mobilization would be 3 dBA lower than during Rock Excavation (except at locations where existing noise levels would make a significant contribution to the total noise).

Note 4: Tabulated L_{dny} values include additive effect of existing noise levels (i.e. values are for ambient noise plus project noise).

TABLE 3: Predicted Yearly Day Night Average Sound Levels (L_{dny} in dBA) During Construction

Qualitative Description of Location	Average L_{dny} (dBA)
Rural	40 - 50
Small town or quiet suburban residential	50
Normal suburban residential	55
Urban residential	60
Noisy urban residential	65
Very noisy urban residential	70
Downtown, major metropolis	75 - 80
Adjoining freeway or near major airport	80 - 90

TABLE 4: Typical Average L_{dny}'s for Various Types of Communities

(from Reference 1)

2.5 PREDICTED NOISE AND VIBRATION LEVELS (Cont'd)

During the Rock Excavation Phase, the predominant noise source at all receptor locations except R2 would be rock drills and, to a lesser extent, the associated air compressors. At location R2, noise from the pile driver would predominate. During the Earth Excavation and Concrete Phase, trucks and loaders on the left bank would be the predominant noise sources for receptors located in Oasis. In Rivervale, trucks hauling earth to the downstream spoil area would be the predominant source.

A detailed listing of source data for construction equipment to be used during the Rock Excavation Phase and during the Earth Excavation/Concrete Phase is presented in Table B1 of Appendix B. Table B2 of Appendix B presents frequency spectra for all of the types of equipment listed in Table B1. The noise levels listed in these tables are indicative for equipment presently in use in British Columbia. New or specially silenced equipment could be significantly quieter.

The L_{dny} values predicted previously in Table 3 were obtained by arithmetically subtracting from the source spectra in Table B2, the appropriate source/receiver path attenuations given in Table 2 and any extra attenuation due to shielding provided by excavations on site. The result of this computation was the predicted sound level in octave bands at specific receptor locations due to a particular type of equipment or activity. These octave band levels were then combined to give overall L_{dny} levels in A-weighted decibels (dBA).

2.5 PREDICTED NOISE AND VIBRATION LEVELS (Cont'd)

The entire procedure was then repeated for other sources (i.e. other types of equipment or activities) and all of the individual L_{dny} values so calculated for a given receptor location were finally added (logarithmically) to yield the L_{dny} at that receptor location due to all sources. A sample calculation showing the determination of the L_{dny} at one receptor location during the rock excavation phase is presented in Table B3 of Appendix B. The results of the complete calculations are summarized in Table B4 of Appendix B for the rock excavation phase and the earth excavation phase and concrete phase.

It is not possible to predict levels of noise and vibration due to blasting as accurately as it is for other construction operations. Empirical data is available however, enabling approximate values to be predicted. The blast noise data used for the present study is from Reference (4) and the ground vibration data is from Reference (5).

The most important factor in determining levels of both noise and vibration from blasting is the amount of explosive charge detonated at any given instant. For this reason, sequential delay triggering devices are commonly used to minimize peak levels. It has been assumed that this technique would be used on the Murphy Creek Project.

It has been estimated that each of the daily blasts proposed for this project would involve in the order of 2000 kg of explosives. Since the number of sequential delays could range anywhere from 10 to as high as 100, the amount of charge per delay (assuming one blast per day) could range anywhere from 200 to 20 kg.

2.5 PREDICTED NOISE AND VIBRATION LEVELS (Cont'd)

Table 5 presents predicted peak levels of noise and ground vibration that would result at the very closest residence (receptor location 0) and at the closest residence in Rivervale (receptor location R) for 200 kg of explosives per delay, for 20 kg per delay and for an intermediate value of 125 kg. per delay.

Explosive Charge per Delay	Predicted Peak Noise Level	
	Receptor Location O in Oasis	Receptor Location R in Rivervale
200 kg	125 dB	113 dB
125 kg	122 dB	110 dB
20 kg	111 dB	99 dB

Explosive Charge per Delay	Predicted Peak Ground Vibration	
	Receptor Location O in Oasis	Receptor Location R in Rivervale
200 kg	6.0 mm/sec	1.5 mm/sec
125 kg	4.0 mm/sec	1.0 mm/sec
20 kg	1.0 mm/sec	0.2 mm/sec

NOTE: Criteria for judging acceptability of blast noise and vibration are discussed subsequently in Section 3.1 of this report.

TABLE 5: Predicted Levels of Noise and Ground Vibration due to Blasting

3.0 ASSESSMENT OF SIGNIFICANCE

3.1 NOISE AND VIBRATION CRITERIA

At present there are no federal, provincial or regional bylaws or regulations governing environmental noise or vibration which would affect the Murphy Creek Hydroelectric Site. Furthermore, there are no indications that any such regulations may be established in the near future.

On site construction noise would be governed by British Columbia Workers' Compensation Board regulations and it would be necessary for any contractors working on the project to ensure that employees are adequately protected against noise. These regulations however, only apply to construction workers within a construction site and not to neighbouring communities. Furthermore, Workers' Compensation Board inspectors generally put emphasis on personal hearing protection devices rather than machinery noise control since construction noise is considered to be a temporary condition.

Where local regulations do not exist, the United States Environmental Protection Agency (EPA), the American Standards Institute (ANSI) and the Acoustical Society of America (ASA) all recommend that the relationship between outdoor noise levels and land use compatibility can best be assessed in terms of L_{dny}. For land use studies of a general nature, where no specific population is under study, approximate L_{dny} criteria for various land uses are recommended by ANSI in the Appendix to their Standard S3.23-1980 (see Figure 3).

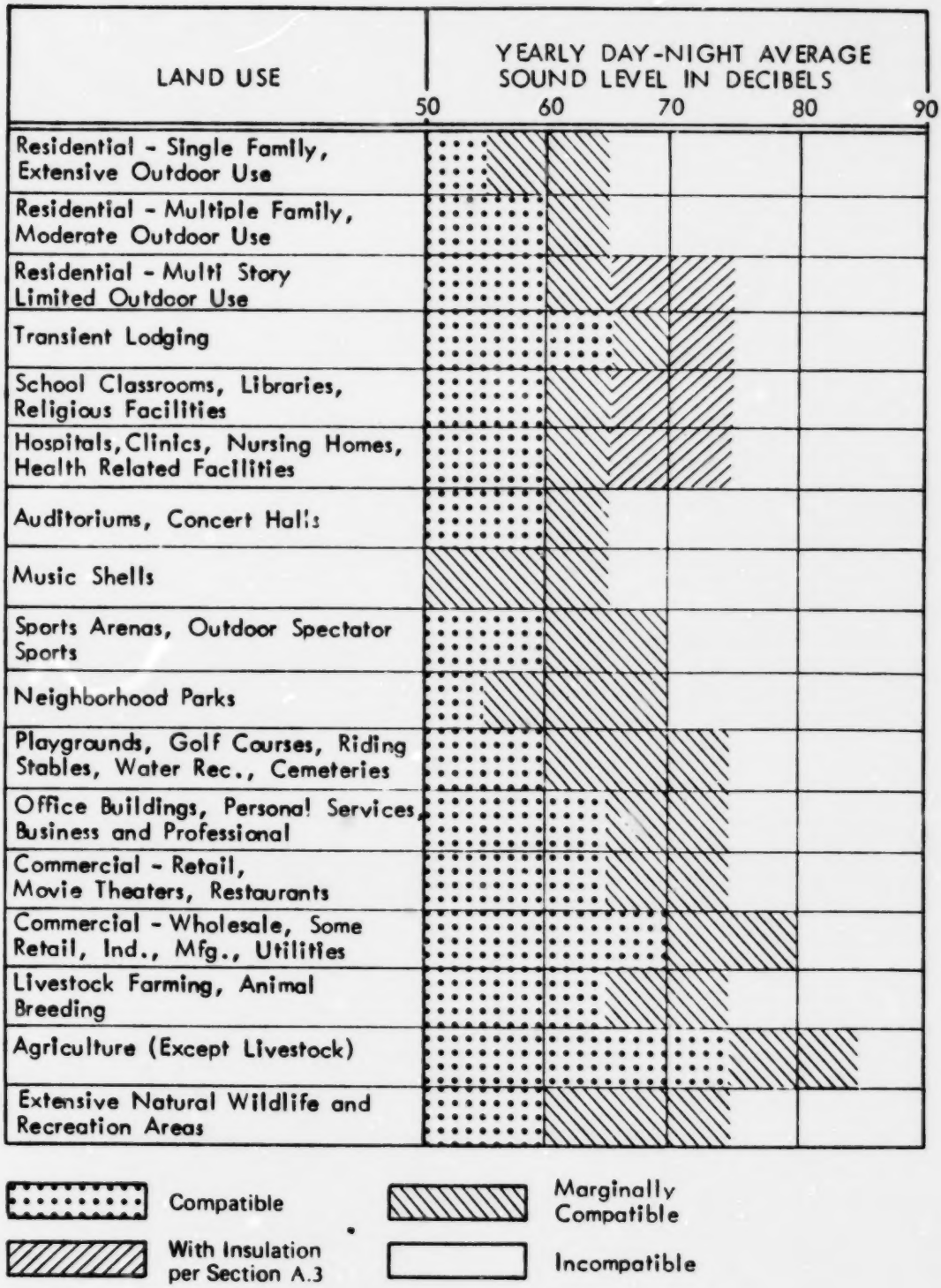
LAND USE
YEARLY DAY-NIGHT AVERAGE SOUND LEVEL IN DECIBELS
50
60
70
80
90
Residential - Single Family, Extensive Outdoor Use
Residential - Multiple Family, Moderate Outdoor Use
Residential - Multi Story Limited Outdoor Use
Transient Lodging
School Classrooms, Libraries, Religious Facilities
Hospitals, Clinics, Nursing Homes, Health Related Facilities
Auditoriums, Concert Halls
Music Shells
Sports Arenas, Outdoor Spectator Sports
Neighborhood Parks
Playgrounds, Golf Courses, Riding Stables, Water Rec., Cemeteries
Office Buildings, Personal Services, Business and Professional
Commercial - Retail, Movie Theaters, Restaurants
Commercial - Wholesale, Some Retail, Ind., Mfg., Utilities
Livestock Farming, Animal Breeding
Agriculture (Except Livestock)
Extensive Natural Wildlife and Recreation Areas
Compatible
Marginally Compatible
With Insulation per Section A.3
Incompatible

FIG. A-1. Land use compatibility with yearly day–night average sound level at a site for buildings as commonly constructed. [For information only; not a part of American National Standard for Sound Level Descriptors for Determination of Compatible Land Use S3.23-1980.]

FIGURE 3: Land Use Compatibility with Yearly Day Night Average Sound Level

3.1 NOISE AND VIBRATION CRITERIA (Cont'd)

When a new noise source is to be introduced to a particular location and population, the probable noise impact can be predicted more accurately by normalizing the L_{dny} that would result from the new source. Normalizing factors used in previous studies and reported by EPA in Reference (1) are presented in Table 6. The normalized L_{dny} is a reasonably accurate predictor of the probable community reaction to the intruding noise and the predicted community reaction is one measure of the noise impact that results upon introduction of a new noise source. The relationship established by previous studies between normalized L_{dny} and community reaction is presented in Figure 4. For the purpose of this study, a degree of noise impact (eg. "insignificant", "low", "moderate", "high", or "extreme") has been assigned to each degree of predicted community reaction as shown in Figure 4.

The degree of community reaction or noise impact is dependent upon the degree of interference experienced with the following activities:

1) Speech Communication in Conversation
2) Telephone Communication
3) Listening to TV and Radio Broadcasts
4) Listening to Music
5) Concentration during Mental Activities
6) Relaxation
7) Sleep

The combination of the above interference effects results in an overall degradation of total well-being and this in turn gives rise to annoyance. Since annoyance is a more familiar concept than "noise impact" it is sometimes more meaningful to refer to degrees of annoyance rather than degrees of noise impact as indicated below:

Insignificant Impact	-	"not annoying"
Low Impact	-	"slightly annoying"
Moderate Impact	-	"moderately annoying"
High Impact	-	"very annoying"
Extreme Impact	-	"extremely annoying"

TABLE 6: COMMUNITY SENSITIVITY CORRECTIONS TO BE ADDED TO L_{dn} OF INTRUDING PROJECT NOISE TO OBTAIN NORMALIZED L_{dn} (ORIGINAL SOURCE - REFERENCE 1)

Type of Correction	Description	Amount of Correction to be Added to Nominal L_{dn}
Seasonal Correction	Summer (or year-round operation).	0
	Winter only (or windows always closed).	-5
Correction for Outdoor Residual Noise	Quiet suburban or rural community (remote from large cities and from industrial activity and trucking).	+10
	Normal suburban community (not located near industrial activity).	+5
	Urban residential community (not immediately adjacent to heavily traveled roads and industrial areas).	0
	Noisy urban residential community (near relatively busy roads or industrial areas).	-5
	Very noisy urban residential community.	-10
Correction for Previous Exposure and Community Attitudes	No prior experience with the intruding noise.	+5
	Community has had some previous exposure to intruding noise but little effort is being made to control the noise. This correction may also be applied in a situation where the community has not been exposed to the noise previously, but the people are aware that bona fide efforts are being made to control the noise.	0
	Community has had considerable previous exposure to the intruding noise and the noise maker's relations with the community are good.	-5
	Community aware that operation causing noise is very necessary and it will not continue indefinitely. This correction can be applied for an operation of limited duration and under emergency circumstances.	-10
Pure Tone or Impulse	No pure tone or impulsive character.	0
	Pure tone or impulse character present.	+5

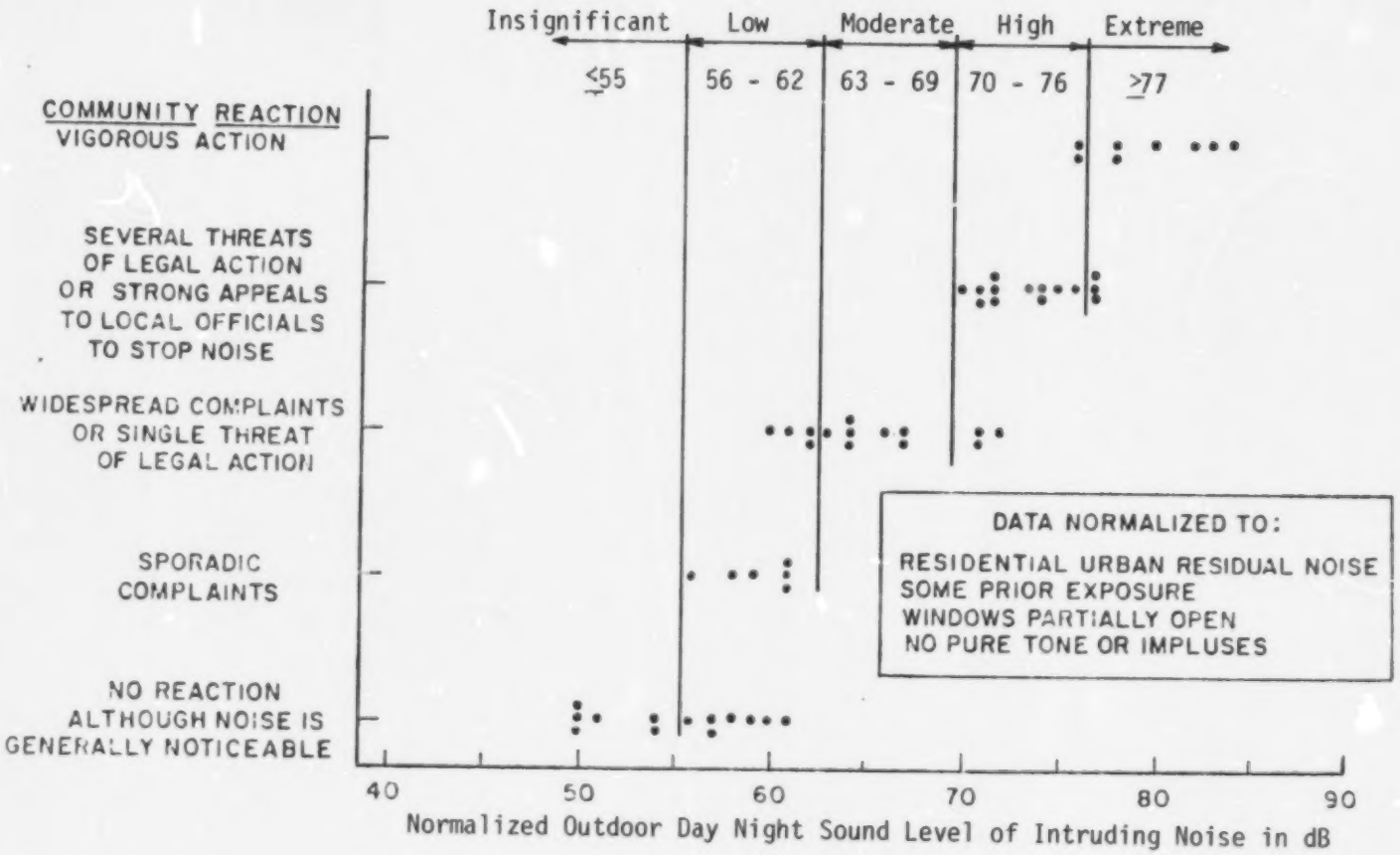

FIGURE 4: Community Reaction to Noises of Many Types as a Function of the Normalized Day Night Sound Level of the Intruding Noise
(from Reference 1 except for noise impact categories)

3.1 NOISE AND VIBRATION CRITERIA (Cont'd)

Noise from blasting is best treated separately from continuous noise in assessing noise impact because its total duration is extremely brief. Appropriate criteria for blast noise are less clearly defined than criteria for more continuous noise but there seems to be some concensus of agreement (4,6,7) that approximately 10-15% of a population will be "very annoyed" by peak noise levels of 128 dB and few, if any, will be "very annoyed" by peak levels of about 122 dB. On this basis, Taylor and Kende (6) recommend a maximum peak noise level of 128 dB to minimize adverse public reaction. However, for the Murphy Creek noise study, a level of 122 dB is considered to be the maximum acceptable.

The criteria most often quoted for ground vibration due to blasting are criteria for avoiding damage to structures, the most common criterion being 50 mm/sec (2 in/sec) peak particle velocity. Such criteria are not appropriate for occupied residences however, since much lower levels of ground vibration can result in significant annoyance to occupants. Oriard (8) states that 0.5 mm/sec to 5 mm/sec is "noticeable" with complaints possible and 5 mm/sec to 50 mm/sec is "severe" with complaints probable.

The annoyance which can result from blasting even when below the "damage" threshold, generally results from "house rattles". For this reason a blast is often more startling indoors than outdoors and a greater degree of annoyance may result in an older house with loose window sashes than in a newer house. The criteria identified above for minimizing annoyance due to blasting are compatible with minimizing "house rattles".

3.2 PREDICTED IMPACTS

In order to predict the noise impact or degree of annoyance that would occur at various receptor locations, the predicted L_{dny} values have been normalized as discussed in the preceding section. The normalizing corrections which have been applied at each receptor location are listed in Table 7. The normalized L_{dny} values and resultant noise impacts are given in Table 8 for each location. These values have been established by adding the total normalizing correction factors to the predicted L_{dny} values of the project noise. (Predicted L_{dny} values of project noise are obtained by logarithmically subtracting the L_{dny} values of existing noise from the predicted L_{dny} values of total noise presented in Table 2.)

The degree of impact which could result from blasting noise and vibration would depend upon the number of blasts per day, the time(s) of day at which the blast(s) occur(s) and the weight of explosives detonated per delay. If the number of blasts per day is minimized (i.e. in the order of 1-3 under normal circumstances), and if the blasts generally occur at the same time(s) each day (preferably during the afternoon or early evening), and finally if the weight of explosives per delay is limited wherever possible to 125 kg or less, then it is estimated that any adverse impact would be low.

The above assessment assumes that the most sensitive noise receptors in Oasis and Rivervale are private residences. However, there may be situations involving particularly sensitive receptors where the impact of construction noise could be somewhat greater than predicted. One example of such a situation is receptor location R where the residence contains a semi-professional sound recording studio on the ground floor level.

Type of Correction	Description	Amount of Correction (dBA) to be Added to Existing L_{dny} at Location Listed Below				
		0	02	03	R	R2
Seasonal Correction	Year-round operation (i.e. windows not always closed)	0	0	0	0	0
Correction for Outdoor Residual Noise	Normally suburban community (not located near industrial activity).	+5	+5	+5		
	Quiet suburban or rural community (remote from large cities and from industrial activity and trucking)				+10	+10
Correction for Previous Exposure and Community Attitudes	Community aware that operation causing noise is necessary and it will not continue indefinately. Noise makers relations with the community are good.	-5	-5	-5	-5	-5
Pure Tone or Impulse Correction	No pure tone or impulsive Character.	0	0	0	0	0
Total Correction		0	0	0	+5	+5

TABLE 7: Normalizing Corrections Applied to Receptor Locations

Construction Phase	Normalized L_{dny} (dBA) at Various Receptor Locations									
	0		02		03		R		R2	
Mobilization	72	High	77	Extreme	68	Moderate	71	High	56	Low
Rock Excavation	75	High	80	Extreme	71	High	74	High	59	Low
Earth Excavation and Concrete	67	Moderate	67	Moderate	62	Low	70	High	60	Low
Site Cleanup	55	Insignificant	53	Insignificant	54	Insignificant	58	Low	44	Insignificant

Note 1) Values in table are for project noise without additive effect of existing noise because noise impact is predicted from normalized L_{dny} of intruding noise (i.e. project noise). (Where existing noise is 10 dBA or more below project noise, the additive effect is negligible.)

Note 2) Noise impact is "Insignificant" for normalized $L_{dny} \leq 55$ dBA

Noise impact is "Low" for normalized 55 dBA $< L_{dny} \leq 62$ dBA

Noise impact is "Moderate" for normalized 62 dBA $< L_{dny} \leq 69$ dBA

Noise impact is "High" for normalized 69 dBA $< L_{dny} \leq 76$ dBA

Noise impact is "Extreme" for normalized 76 dBA $< L_{dny}$

TABLE 8: Normalized L_{dny} of Project Noise and Resultant Noise Impact at Receptor Locations (No Mitigative Measures)

4.0 AVAILABLE MEANS OF MITIGATION

Various means are available to reduce the predicted noise impacts in Oasis and Rivervale. The possibilities described below are technically feasible but would require further investigation by B. C. Hydro to establish whether or not they would be practicable on this particular project. In addition, benefit/cost analyses would probably be necessary for each available means of mitigation. Costs cannot be quantified at this time since the manner in which the various mitigative measures could be implemented would require study by B. C. Hydro. The reduction in normalized L_{dny} that would result from various means of mitigation at each receptor location is indicated in Tables 9 - 13.

4.1 CONTROLS ON CONSTRUCTION EQUIPMENT

Reference to Table B4 in Appendix B indicates that a few sources in particular would predominate the noise environment throughout this construction project. During the rock excavation phase, the predominant sources would be pneumatic rock drills and their associated air compressors. During the earth excavation and concrete phase, the predominant sources would be off-highway trucks working on the left (east) bank and concrete transit trucks working primarily on the right (west) bank. Any noise control on these predominant sources would lower overall noise in Oasis and Rivervale. However, noise control on other sources with no control of the predominant sources would result in little or no noise reduction in these communities.

For each of the predominant sources mentioned above, the noise level produced depends upon the type, size, make, age and condition of the equipment. The noise levels that have been assumed in the present analysis (i.e. for "no mitigative measures" in Tables 9 to 13) are

TABLE 9: Effect of Various Mitigating Measures on Predicted Noise Impact at Location 0

Description of Mitigative Measure	Normalized L_{dny} (dBA) of Project Noise and Resultant Noise Impact			
	Mobilization Phase	Rock Excavation Phase	Earth Excav. and Concrete Phase	Site Cleanup Phase
i) No mitigative measures	72 High	75 High	67 Moderate	55 Insignificant
ii) Specified noise limits on rock drills and compressors (90 dBA for drills and 70 dBA for compressors as discussed on page 21)	67 Moderate	70 High	67 Moderate	55 Insignificant
iii) Specified noise limits on rock drills and compressors as in ii) above plus provision of 3 m high roadside barrier to shield Riverside from noise produced by trucks hauling waste during rock excavation phase from right bank to waste dump in vicinity of Billy Creek.	67 Moderate	70 High	67 Moderate	55 Insignificant
iv) Elimination of nighttime (22:00 hours to 07:00 hours) drilling on right bank and nighttime use of left bank waste dump during mobilization and rock excavation phases plus elimination of nighttime earth excavation on left bank during earth excavation and concrete phase. In addition, increase by 60% the number of drills, trucks, loaders, dozers, etc. to compensate for curtailed nighttime activities.	65 Moderate	68 Moderate	65 Modeate	55 Insignificant
v) Measures iii) and iv) together	61 Low	64 Moderate	65 Moderate	55 Insignificant
vi) Supplementary ventilation or air conditioning on noise exposed side of residence	67 Moderate	70 High	62 Low	50 Insignificant
vii) Supplementary ventilation or air conditioning plus storm windows on noise exposed side of residence plus provision of quiet (i.e. screened) outdoor area if backyard is exposed to noise.	62 Low	65 Moderate	57 Low	45 Insignificant
viii) Same as iii) plus supplementary ventilation or air conditioning as described in vi) above.	62 Low	65 Moderate	62 Low	50 Insignificant

TABLE 10: Effect of Various Mitigating Measures on Predicted Noise Impact at Location 02

Description of Mitigative Measure	Normalized L_{dny} (dBA) of Project Noise and Resultant Noise Impact			
	Mobilization Phase	Rock Excavation Phase	Earth Excav. and Concrete Phase	Site Cleanup Phase
i) No mitigative measures	77 Extreme	80 Extreme	67 Moderate	53 Insignificant
ii) Specified noise limits on rock drills and compressors (90 dBA for drills and 70 dBA for compressors as discussed on page 21)	69 Moderate	72 High	67 Moderate	53 Insignificant
iii) Specified noise limits on rock drills and compressors as in ii) above plus provision of 3 m high roadside barrier to shield Riverside from noise produced by trucks hauling waste during rock excavation phase from right bank to waste dump in vicinity of Billy Creek.	69 Moderate	72 High	67 Moderate	53 Insignificant
iv) Elimination of nighttime (22:00 hours to 07:00 hours) drilling on right bank and nighttime use of left bank waste dump during mobilization and rock excavation phases plus elimination of nighttime earth excavation on left bank during earth excavation and concrete phase. In addition, increase by 60% the number of drills, trucks, loaders, dozers, etc. to compensate for curtailed nighttime activities.	70 High	73 High	65 Moderate	53 Insignificant
v) Measures iii) and iv) together	63 Moderate	66 Moderate	65 Moderate	53 Insignificant
vi) Supplementary ventilation or air conditioning on noise exposed side of residence	72 High	75 High	62 Low	48 Insignificant
vii) Supplementary ventilation or air conditioning plus storm windows on noise exposed side of residence plus provision of quiet (i.e. screened) outdoor area if backyard is exposed to noise.	67 Moderate	70 High	57 Low	43 Insignificant
viii) Same as iii) plus supplementary ventilation or air conditioning as described in vi) above.	66 Moderate	67 Moderate	62 Low	48 Insignificant

TABLE 11: Effect of Various Mitigating Measures on Predicted Noise Impact at Location 03

Description of Mitigative Measure	Normalized L_{dny} (dBA) of Project Noise and Resultant Noise Impact			
	Mobilization Phase	Rock Excavation Phase	Earth Excav. and Concrete Phase	Site Cleanup Phase
i) No mitigative measures	68 Moderate	71 High	58 Low	54 Insignificant
ii) Specified noise limits on rock drills and compressors (90 dBA for drills and 70 dBA for compressors as discussed on page 21)	63 Moderate	66 Moderate	58 Low	54 Insignificant
iii) Specified noise limits on rock drills and compressors as in ii) above plus provision of 3 m high roadside barrier to shield Riverside from noise produced by trucks hauling waste during rock excavation phase from right bank to waste dump in vicinity of Billy Creek.	63 Moderate	66 Moderate	58 Low	54 Insignificant
iv) Elimination of nighttime (22:00 hours to 07:00 hours) drilling on right bank and nighttime use of left bank waste dump during mobilization and rock excavation phases plus elimination of nighttime earth excavation on left bank during earth excavation and concrete phase. In addition, increase by 60% the number of drills, trucks, loaders, dozers, etc. to compensate for curtailed nighttime activities.	61 Low	64 Moderate	54 Insignificant	54 Insignificant
v) Measures iii) and iv) together	56 Low	59 Low	54 Insignificant	54 Insignificant
vi) Supplementary ventilation or air conditioning on noise exposed side of residence	62 Low	66 Moderate	53 Insignificant	49 Insignificant
vii) Supplementary ventilation or air conditioning plus storm windows on noise exposed side of residence plus provision of quiet (i.e. screened) outdoor area if backyard is exposed to noise.	57 Low	61 Low	48 Insignificant	44 Insignificant
viii) Same as iii) plus supplementary ventilation or air conditioning as described in vi) above.	57 Moderate	61 Moderate	53 Insignificant	49 Insignificant

TABLE 12: Effect of Various Mitigating Measures on Predicted Noise Impact at Location R

Description of Mitigative Measure	Normalized L_{dny} (dBA) of Project Noise and Resultant Noise Impact			
	Mobilization Phase	Rock Excavation Phase	Earth Excav. and Concrete Phase	Site Cleanup Phase
i) No mitigative measures	71 High	74 High	70 High	58 Low
ii) Specified noise limits on rock drills and compressors (90 dBA for drills and 70 dBA for compressors as discussed on page 21)	69 Moderate	72 High	70 High	58 Low
iii) Specified noise limits on rock drills and compressors as in ii) above plus provision of 3 m high roadside barrier to shield Riverside from noise produced by trucks hauling waste during rock excavation phase from right bank to waste dump in vicinity of Billy Creek.	66 Moderate	69 Moderate	70 High	58 Low
iv) Elimination of nighttime (22:00 hours to 07:00 hours) drilling on right bank and nighttime use of left bank waste dump during mobilization and rock excavation phases plus elimination of nighttime earth excavation on left bank during earth excavation and concrete phase. In addition, increase by 60% the number of drills, trucks, loaders, dozers, etc. to compensate for curtailed nighttime activities.	66 Moderate	69 Moderate	64 Moderate	58 Low
v) Measures iii) and iv) together	59 Low	67 Moderate	64 Moderate	58 Low
vi) Supplementary ventilation or air conditioning on noise exposed side of residence	63 Moderate	69 Moderate	65 Moderate	53 Insignificant
vii) Supplementary ventilation or air conditioning plus storm windows on noise exposed side of residence plus provision of quiet (i.e. screened) outdoor area if backyard is exposed to noise.	58 Low	64 Moderate	60 Low	48 Insignificant
viii) Same as iii) plus supplementary ventilation or air conditioning as described in vi) above.	56 Low	67 Moderate	65 Moderate	53 Insignificant

TABLE 13: Effect of Various Mitigating Measures on Predicted Noise Impact at Location R2

Description of Mitigative Measure	Normalized L_{dny} (dBA) of Project Noise and Resultant Noise Impact			
	Mobilization Phase	Rock Excavation Phase	Earth Excav. and Concrete Phase	Site Cleanup Phase
i) No mitigative measures	56 Low	59 Low	60 Low	44 Insignificant
ii) Specified noise limits on rock drills and compressors (90 dBA for drills and 70 dBA for compressors as discussed on page 21)	55 Insignificant	58 Low	60 Low	44 Insignificant
iii) Specified noise limits on rock drills and compressors as in ii) above plus provision of 3 m high roadside barrier to shield Riverside from noise produced by trucks hauling waste during rock excavation phase from right bank to waste dump in vicinity of Billy Creek.	52 Insignificant	54 Insignificant	60 Low	44 Insignificant
iv) Elimination of nighttime (22:00 hours to 07:00 hours) drilling on right bank and nighttime use of left bank waste dump during mobilization and rock excavation phases plus elimination of nighttime earth excavation on left bank during earth excavation and concrete phase. In addition, increase by 60% the number of drills, trucks, loaders, dozers, etc. to compensate for curtailed nighttime activities.	51 Insignificant	54 Insignificant	54 Insignificant	44 Insignificant
v) Measures iii) and iv) together	45 Insignificant	53 Insignificant	54 Insignificant	44 Insignificant
vi) Supplementary ventilation or air conditioning on noise exposed side of residence	52 Insignificant	54 Insignificant	55 Insignificant	39 Insignificant
vii) Supplementary ventilation or air conditioning plus storm windows on noise exposed side of residence plus provision of quiet (i.e. screened) outdoor area if backyard is exposed to noise.	47 Insignificant	49 Insignificant	50 Insignificant	34 Insignificant
viii) Same as iii) plus supplementary ventilation or air conditioning as described in vi) above.	45 Insignificant	53 Insignificant	55 Insignificant	39 Insignificant

4.1 CONTROLS ON CONSTRUCTION EQUIPMENT (Cont'd)

indicative of equipment in common use today. They do not represent the noisiest equipment to be found, nor do they represent the new, well silenced equipment which has become available over the past few years.

In the case of rock drills, the new "valveless" drills and drills equipped with air exhaust silencers are considerably quieter than the older models as are pneumatic drills with "down-the-hole" hammers. Some hydraulic drills are also significantly quieter (those in which the engine driving the hydraulic pump is well silenced). Figure 5, taken from a manufacturer's brochure (9), illustrates the differences in noise level to be expected from several types of drills. New, silenced air compressors are also available for use with the pneumatic drills (eg. Ingersoll-Rand "whisperized" compressors and Atlas Copco "Silensair" compressors). Noise levels of 70 dBA or less at a distance of 15 m are attainable with these new compressors whereas a level of 87 dBA has been assumed for the standard compressor. Table 14 illustrates noise levels produced by several currently available models of rock drills and compressors (all in the size range assumed for this study).

In the case of off-highway trucks and concrete transit trucks, noise levels have not changed dramatically over the past six or seven years. Hence the variation amongst comparable trucks is fairly limited (in the order of 5 dBA) except where a truck is very old or poorly maintained. Consequently the potential benefit to be gained by specifying noise limits on trucks is not great enough to justify the extra cost which could result.

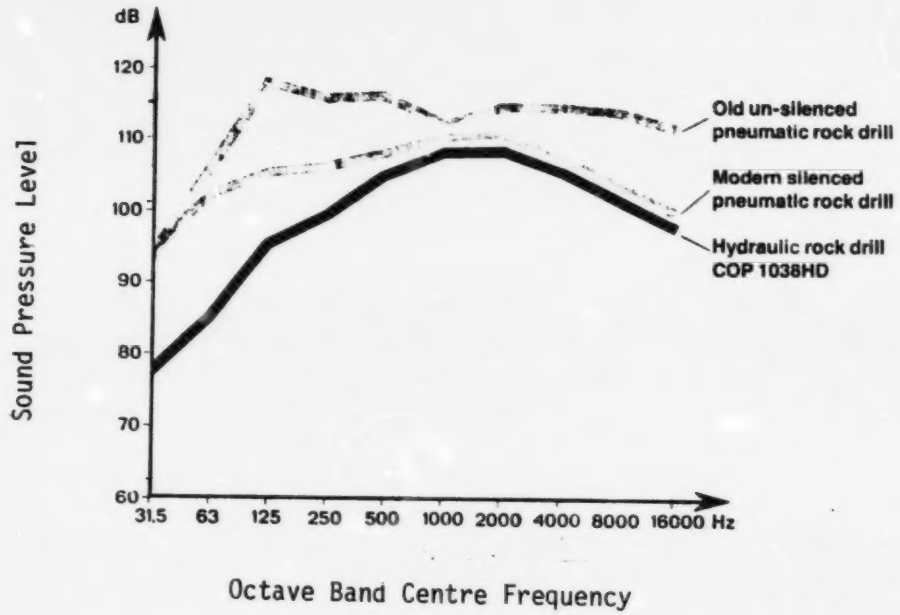

Figure 5: Comparison of Noise Levels Produced by Various Types of Rock Drills (Sound Pressure Levels Measured in Octave Bands at Drill Operator's Position)
(From Reference 9)

Rock Drills (65 - 155 mm bore)

Manufacturer	Type	Model	Noise Level (dBA) @ 15 m
Gardner Denver	Unsilenced pneumatic (top hammer)	PR 123	100
	Silenced pneumatic (top hammer)	PR 123	96
	Hydraulic	HPR 1	89
Ingersoll-Rand	pneumatic (top hammer)	ECM 350	97 (approximate)
	Hydraulic	ECM 450	97 (approximate)
Atlas Copco	pneumatic ("down the hole" hammer)	ROC 601/COP 42	83 (at hole depth = 1m)
	Hydraulic	ROC 712H/COP 1036	82-87 (approximate)

Air Compressors

Manufacturer	Type	Model	Noise Level (dBA) @ 15 m
Gardner Denver	Unsilenced	750 CFM	83
	Silenced	750 CFM	68
Ingersoll-Rand	Unsilenced (750 CFM)	DXL 750 P	87
	Unsilenced (1100 CFM)	DXL 1100	89
	Silenced ("Whisperized") (750 CFM)	XP750 WGM	69
	Silenced ("Whisperized") (1100 CFM)	P1100	69
Atlas Copco	Silenced Rotary Screw ("Silensair") (750 CFM)	XAS350	68
	Silenced Rotary Screw ("Super Silensair") (750 CFM)	XASS350	63

TABLE 14: Noise Levels Produced by New Rock Drills and Compressors

4.1 CONTROLS ON CONSTRUCTION EQUIPMENT (Cont'd)

In view of the above comments, one possible approach to noise control would be to specify a maximum permissible noise level for rock drills and compressors such that new, suitably silenced hydraulic equipment and possibly new, well silenced pneumatic equipment would meet the requirements but older unsilenced equipment would not. Since hydraulic drills and certain types of pneumatic drills are available which produce noise levels below 90 dBA at 15 m, 90 dBA would be a reasonable limit to specify. New, silenced air compressors are available which produce noise levels in the 63-69 dBA range at 15 m. Therefore a reasonable limit to specify would be 70 dBA which is still 17 dBA quieter than the level assumed in this report for an unsilenced compressor. No noise limits need be specified for other equipment.

The effect of using a larger number of smaller capacity machines or vice versa, relative to the numbers assumed in the calculations would be rather small as far as noise is concerned. For example, a 60% increase in the numbers of a certain machine would raise noise levels by only 2 dB and a 100% increase would raise levels by 3 dB. These increases would be offset by a tendency for smaller capacity machines to be slightly quieter than larger capacity machines. Hence, selecting an optimum balance between number of machines and machine capacity does not represent a very significant noise control strategy.

4.2 NOISE CONTROL BARRIERS ON SITE

Noise from off-highway trucks hauling waste rock from the right bank to the proposed waste dump on the left bank (in the vicinity of Billy Creek) would be perceived as a predominant source of noise by residents of Rivervale. However, by construcing a roadside barrier approximately 3 m high relative to the road surface, noise propagated from these trucks in the direction of Rivervale could be reduced by about 7 dBA, which would reduce the overall noise level in Rivervale (from all sources combined) by 3-4 dBA. The barrier need only be provided on that side of the road closest to Rivervale and it should be as close to the edge of the road as possible. The barrier material would be continuous, without openings and must weigh at least 5 kg/m^2. It could consist of fences, earth berms, earth cuts, or any combination of these. The proposed bridge across the river would also require an appropriate barrier along the downstream side.

Unfortunately, the roadside barrier described above would be of little benefit to the residents of Oasis since they would be overlooking this haul road from above. For the same reason, it is unlikely that other noise control barriers would be effective in reducing noise from other sources on the site. It is possible however, that once other haul routes are identified more specifically, roadside barriers could be a possible means of reducing noise during the earth excavation and concrete phase from off-highway trucks operating on the left bank and possibly concrete transit trucks. Any potential benefit from these latter barriers cannot be predicted at this time however and hence should not be relied upon for reducing noise impact.

4.3 RESTRICTED HOURS OF WORK

Since noise during the nighttime results in considerably greater noise impact than noise during the daytime, significant reductions in impact could be achieved by eliminating the noisiest construction operations during this period. For the purpose of analysis, a 10 dBA weighting factor was added in calculating L_{dny} for noise generated between the hours of 10:00 p.m. and 7:00 a.m. To achieve signficant reductions in nighttime noise levels, curtailment of drilling during the mobilization and rock excavation phases and/or earth excavation on the left bank during the earth excavation and concrete phase would be the most effective.

If the schedules for these operations are critical, then extra equipment would have to be provided by the contractor to increase production during the daytime hours.

4.4 SUPPLEMENTARY VENTILATION OR AIR CONDITIONING FOR RESIDENCES

The noise impact or annoyance experienced by local residents would result largely from interference with activities carried on inside the home. Since most homes rely upon opening windows for ventilation in the summertime the noise impact assessment carried out has assumed partially open windows during at least part of the year. If an alternate means of ventilation is provided on the noise exposed side of the residence, windows could be kept closed thereby resulting in lower interior noise levels.

4.4 SUPPLEMENTARY VENTILATION OR AIR CONDITIONING FOR RESIDENCES (Cont'd)

Air conditioning is preferable to straight ventilation because there might still be some tendency to open windows on warm summer days and nights even if supplementary ventilation is provided. Such measures would not generally be necessary on the side of the house which is shielded from the noise source since levels on the shielded side would be about 15 dBA lower.

If the measures described above are taken to ensure that windows exposed to construction noise would likely remain closed, a further -5 dB normalizing correction can be applied to the predicted L_{dny} values. This represents a significant reduction in noise impact.

Houses with existing forced air heating systems could be easily modified to distribute fresh air during summer months. This would simply require the addition of a fresh air intake to the furnace. A capability for cooling could also be added to an existing forced air heating system although the cost would be substantially higher than for fresh air ventilation alone.

For houses without forced air systems, ceiling exhaust fans and acoustically lined exhaust ducts would have to be installed in the most noise sensitive rooms located on the noise exposed side of the house. Exhaust outlets could be through the roof or beneath the eaves. In order to provide some degree of cooling in addition to ventilation, two or more window air conditioners could be installed in rooms located on the quiet side of the house.

These units in conjunction with the exhaust fans described above, would provide a flow of cool air from the quiet side of the building through any noise sensitive rooms located on the noise exposed side of

4.4 SUPPLEMENTARY VENTILATION OR AIR CONDITIONING FOR RESIDENCES (Cont'd)

the house. If window air conditioners were located in bedrooms, custom designed silencing hoods would be required to reduce noise from the units.

4.5 ADDITIONAL NOISE CONTROL AT RESIDENCES

Noise impact or annoyance results not only from high interior noise levels. It is also caused by high exterior noise levels, particularly during the summer when outdoor living occurs more frequently. Therefore, to achieve a further significant reduction in noise impact once supplementary ventilation or air conditioning has been provided, it would be necessary to improve both the indoor and outdoor noise environments.

The addition of conventional storm windows on the noise exposed side of a house would reduce interior noise levels by 5 dBA or more which represents a fairly significant improvement. Outside the house, it would be possible to provide one relatively quiet location by protecting a patio or sundeck from the construction noise by providing a solid fence or screen. This fence would require an impervious surface weighing at least 10 kg/m^2 and should be as high as practical (eg. 1.5 m). Suitable materials, considering acoustical requirements only, would include 19 mm thick wood, 4 mm safety glass or 9 mm plexiglass. For houses oriented such that the back yard would be shielded from construction noise by the house itself, no special screens or fences would be necessary. In terms of normalized L_{dny}, a reduction of approximately 5 dB could be achieved by providing both the storm windows and a quiet outdoor space.

5.0 CONCLUSIONS

1) If no special noise mitigating measures are taken during construction, virtually all of Oasis and Rivervale would experience some degree of noise impact ranging from "Low" to "Extreme" depending upon location and the phase of construction that is in progress.

2) By limiting allowable noise levels on rock drills and compressors, by eliminating some activities during nighttime or by controlling noise at nearby residences, the noise impacts could be reduced significantly such that they range from "Insignificant" to "High" (depending upon construction phase and receiver location). By combining two or more of these measures, even greater reductions would be possible.

3) Noise and vibration from blasting would not be a major source of annoyance in the communities adjacent to the site providing that the number of blasts per day did not exceed two or three, the blasts were consistently scheduled to occur at periods of the day when they would be least likely to interfere with residents' sleep and providing that sequential delays were used such that the maximum charge per delay would be approximately 125 kg.

6.0 REFERENCES

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APPENDIX A

Baseline Noise Monitoring

BASELINE NOISE MONITORING

Two different sets of instrumentation were used for monitoring baseline (i.e. existing) noise levels. System #1 was used at 563 3rd Avenue, Rivervale on January 27, 1982 and at 11 Hanna Drive, Oasis on January 28, 1982. System #2 was used at 11 Hanna Drive, Oasis on January 27, 1982. Each system is described below and photographs of both monitoring locations are presented on the following pages.

System #1 consisted of a Bruel & Kjaer (B&K) Type 4165 microphone, a B&K Type 2204 Precision Sound Level Meter and a GenRad Model 1945 Community Noise Analyser. System #2 consisted of a B&K Type 4175 microphone, a B&K Type 2225 sound level meter and a B&K Type C101 data storer. Both systems included microphone extension cables and windscreens and were calibrated prior to use with a B&K Type 4230 calibrator.

View Looking towards site

View looking towards house from street with site in background

Noise Monitoring Location 0 (11 Hanna Drive, Oasis)

Harford, Kennedy, Wakefield Ltd.

View looking towards site

View looking along street in direction opposite to site

Noise Monitoring Location R (563 3rd Avenue, Rivervale)

Harford, Kennedy, Wakefield Ltd.

APPENDIX B

Construction Equipment Noise Data

Column No.	1	2	3	4	5	6	7	8	9	10	11
Phase	Equipment	Source of Noise Data	Noise Level at ref. distance of 15 m from source (dBA)	Duty Cycle *	Leq at 15m from source (dBA)	Number of machines on site	Total Leq for each equip. type (referenced to 15 m)	Daytime hours of operation per 24 hrs **	Nighttime hours of operation per 24 hrs **	Total L_{dny} for each equip. type (referenced to 15 m)	Acoustic centre of source (see Figure 1)
Rock Excavation	Pneumatic Rock Drill	A, B	97	0.75	96	10	106	13	8	112	1
	Front End Loader	C, B	90	0.75	89	2	92	13	8	98	1
	45 - 75 tonne truck	A, C, B	89	0.5	86	4	92	13	8	98	1
	45 - 75 tonne truck	A, C, B	89	0.5	86	4	92	13	8	98	8
	Bus	B	85	1.0	85	4	91	0.2	0.1	78	2
	Pile Driver	D	101	0.75	100	1	100	13	0***	97	3
	Compress. for Rock Drill	B	87	1.0	87	10	97	13	8	103	1
	Compress. for Pile Driv.	B	88	1.0	88	1	88	13	0***	85	3
	Dozers in U/S Spoil Area	-	Insignificant	-	-	2	-	-	-	-	-
Earth Excavation	Front End Loader	C, B	90	0.75	89	2	92	13	8	98	4
	Hydraulic Backhoe	B	88	0.75	87	1	87	13	8	93	4
	45 - 75 Tonne Truck	A, B, C	89	0.5	86	8	95	13	8	101	4
	Dozers in Spoil Area	B, E	88	0.75	87	2	90	13	8	96	5
	230 tonne Mobile Crane (for Drag Line)	B, F	89	0.5	86	1	86	13	8	92	3
Concrete	Concrete Batch Plant	A	90	1.0	90	1	90	13	2	91	6
	Conveyor	-	Insignificant	-	-	1	-	-	-	-	-
	Concrete Transit Truck	B	87	0.125	78	5	85	5	2	85	2
	Electric Whirley Crane	-	Insignificant	-	-	3	-	-	-	-	-
	30 tonne Mobile Crane	B	84	0.5	81	2	84	13	8	90	1
	Aggregate Process. Plant	A	94	1.0	95	1	95	13	2	96	7
	Front End Loader	B	89	0.5	86	1	86	13	2	87	7
	Bus	B	85	1.0	85	8	94	0.2	0.1	81	2

NOTE: Key to Column 2 and footnotes are listed on following page.

TABLE B1: Construction Equipment Noise Levels (dBA)

* Duty cycle is % of working time at or near full power. Duty cycles for trucks were determined from detailed calculations taking into account percentage of time trucks are travelling, loading, unloading, waiting, etc. Duty cycles for other equipment were estimated.

** Hours are net after deducting meal and coffee breaks

*** Assumes pile driver quits at 10:00 p.m.

Key to Column No. 2 (Sources of Noise Data)

A - Measurement by Harford, Kennedy, Wakefield Ltd. (HKW) at Revelstoke Dam construction site.

B - Field data from Reference (2) in Section 6.0 of this report.

C - Measurement by HKW at open pit mine near Sparwood, B. C.

D - Measurement by HKW on pneumatic pile driver driving steel sheet piles in Delta, B. C.

E - Field data from Reference (11) in Section 6.0 of this report.

F - Field data from Reference (10) in section 6.0 of this report.

Notes from Table B1 (Construction Equipment Noise Levels)

Phase	Equipment	Total L_{dny} (dBA) for each equipment type (referenced to 15m) from Table B1	Octave Band Noise Levels (dBA)						
			Octave Band Centre Frequencies (Hz)						
			63	125	250	500	1000	2000	4000
Rock Excavation	Pneumatic Rock Drills	112	97	108	103	107	106	104	101
	Front End Loaders	98	92	95	93	89	92	92	82
	45-75 Tonne Trucks	101	98	99	96	97	96	93	91
	Buses	78	75	77	76	75	74	68	62
	Pile Driver	97	82	91	83	89	91	92	89
	Compressors for Rock Drills	103	106	112	103	101	99	93	88
	Compressor for Pile Driver	85	88	94	85	83	81	75	70
Earth Excavation	Front End Loaders	98	92	95	93	89	92	92	82
	Hydraulic Backhoe	93	90	92	91	90	89	83	77
	45-75 Tonne Trucks	101	98	99	96	97	96	93	91
	Dozers in Spoil Area	96	92	95	89	93	89	89	87
	230 Tonne Crane (Drag Line)	92	89	91	90	89	88	82	76
Concrete	Concrete Batch Plant	91	90	89	81	85	84	93	76
	Concrete Transit Trucks	85	82	84	83	82	81	75	69
	30 Tonne Mobile Cranes	90	87	89	88	87	86	80	74
	Aggregate Processing Plant	86	82	82	79	85	81	74	66
	Front End Loaders	87	81	84	82	78	81	81	71
	Buses	81	78	80	79	78	77	71	65

Table B2: Noise Source Spectra Used for Construction Noise Level Predictions (Octave Band Sound Pressure Levels in dB at Reference Distance of 15 m)

Octave Band Centre Frequency (Hz)	63	125	250	500	1000	2000	4000	L_{day} (dBA)
SOURCE LOCATION 1								
Rock Drills	97	108	103	107	106	104	101	
Path Attenuation	-27	-29	-31	-39	-38	-39	-40	
Sound Pressure Level, SPL drills	70	79	72	68	68	65	61	72
Compressors	106	112	103	101	99	93	88	
Path Attenuation	-27	-29	-31	-39	-38	-39	-40	
SPL Compressors	79	83	72	62	61	54	48	70
Trucks	95	96	93	94	93	90	88	
Barrier Attenuation	-11	-13	-15	-18	-21	-22	-23	
Path Attenuation	-27	-29	-31	-39	-38	-39	-40	
SPL Trucks	57	54	47	37	34	29	25	43
Loaders	92	95	93	89	92	92	82	
Barrier Attenuation	-11	-13	-15	-18	-21	-22	-23	
Path Attenuation	-27	-29	-31	-39	-38	-39	-40	
SPL Loaders	54	53	47	32	33	31	19	42
SOURCE LOCATION 2								
Buses	72	74	73	72	71	65	59	
Path Attenuation	-22	-22	-22	-22	-23	-24	-27	
SPL Buses	50	52	51	50	48	41	32	52
SOURCE LOCATION 3								
Pile Driver	82	91	83	89	91	92	89	
Path Attenuation	-32	-32	-33	-39	-40	-39	-44	
SPL Piledriver	50	59	50	50	51	53	45	57
Compressor for Piledriver	88	94	85	83	81	75	70	
Path Attenuation	-32	-32	-33	-39	-40	-39	-44	
SPL Pile Drive Compressor	56	62	52	44	41	36	26	49
SOURCE LOCATION 8								
Trucks	95	96	93	94	93	90	88	
Path Attenuation	28	28	29	29	31	34	43	
SPL Trucks	67	68	64	65	62	56	45	66
TOTAL L_{dny} at 0	80	84	75	69	69	66	61	75

TABLE B3: Sample Calculation (Determination of L_{dny} (dBA) at at Receptor Location 0 during Rock Excavation Phase)

Receptor Location	Pneumatic Rock Drills	Air Comp. for Rock Drills	Off-Highway Trucks (Location 1)	Off-Highway Trucks (Location 8)	Front End Loaders	Crew Buses	Pile Driver	Air Comp. for Pile Driver		All Sources Combined
0	72	70	46	66	42	52	57	49		75
02	79	73	50	62	45	46	58	50		80
03	68	65	41	62	37	29	52	44		71
R	65	57	54	66	51	31	56	47		69
R2	46	41	36	52	33	13	44	39		54

Rock Excavation Phase

Receptor Location	Drag Line	Dozers in Spoil Area	Off-Highway Trucks	Front End Loaders	Hydraulic Backhoe	Crew Buses	Aggregate Proc. Plant	Loader in Aggregate Proc. Plant	Concrete Batch Plant	Concrete Transit Trucks	Mobile Cranes	All Sources Combined
0	53	57	61	57	54	55	43	44	55	62	53	67
02	56	58	62	57	55	49	47	45	58	56	59	67
03	46	49	54	50	46	32	36	38	45	39	47	58
R	52	59	60	57	53	34	44	44	48	41	44	65
R2	43	47	52	47	45	16	37	35	27	23	26	55

Earth Excavation and Concrete Phase

Note: Calculated values in tables above do not include presently existing ambient noise at receptor locations.

Table B4: Calculated L_{dny} Values (in dBA) at Various Receptor Locations due to Individual Sources